Semi-Autonomous Flight Environment Tug (SAFETug)

Presenters:
Robert Morris (PI, Ames)
E. Vincent Cross (Lockheed Martin/JSC)
Robert C. Garrett (Lockheed Martin Advanced Technology Laboratories

Contributors

- Ron Archer (Lockheed Martin/JSC)
- Mai Lee Chang (JSC)
- Jerry Franke (Lockheed Martin Advanced Technology Laboratories)
- Garrett Hemann (CMU)
- Waqar Malik (UARC/Ames)
- Kerry McGuire (JSC)
- Corina Pasearanu (Ames)
- Shelby Thompson (Lockheed Martin/JSC)

Outline

- Overview of project
  - Big question being addressed
  - Current practice and limitations
  - The *autonomous engines off taxiing scenario*
  - Overview of technical approach
  - Performance metrics under evaluation
- SafeTug Architecture
  - Surface control automation
  - Human-machine interface design
  - Autonomy capabilities for self-driving towing vehicles
- Experiments and Results
  - ASSET simulation tool
  - Results
- Future work

How can we improve the capacity of the national airspace?

- Congestion at key airports as the area in which the traffic capacity problem is most prominent.
- Capacity gain requires construction of new runways and expansion of surface area for taxiing.
- Capacity gain means more complexity in Air Traffic Control (ATC) operations, increasing risk of human error, operator workload, and the potential for inefficiencies in operations.
- Capacity gain also means potentially harmful effects on the environment, such as more noise and air pollution, and higher fuel costs for taxiing aircraft.
- *The practical difficulties of increasing capacity through airport expansion introduce the desire for enhanced airport ground movement efficiency by the* ***intelligent use*** *of the existing resources.*

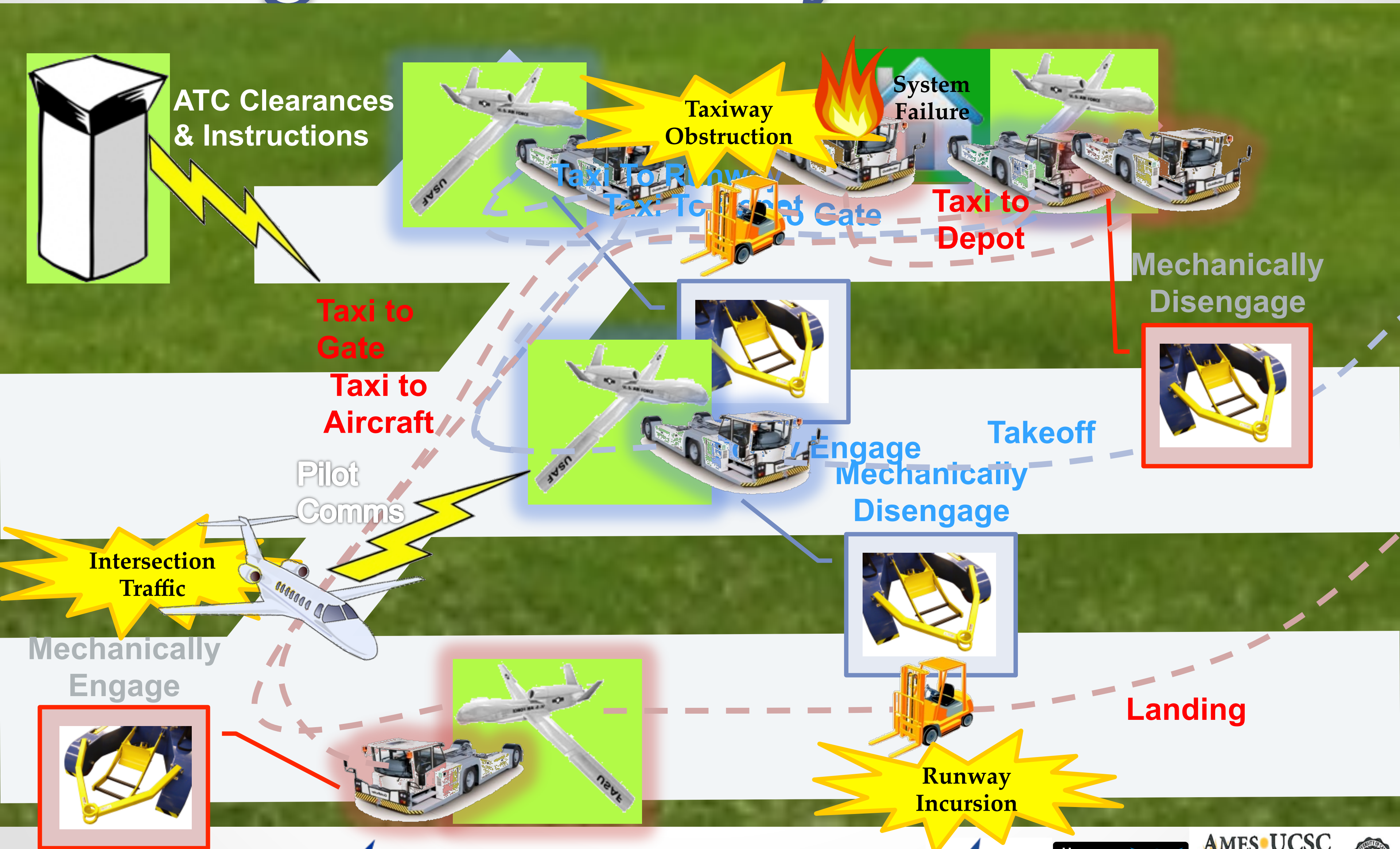
Current practice and limitations

- Aircraft depend on their engines or human-driven towing vehicles during departure or arrival ground operations.
  - Departure: pushback, engines-start, taxi-out, engine warm-up
  - Arrival: taxi-in, engine cool-down, shutdown.
- Improvement areas:
  - Efficiency in operations
    - Higher precision navigation
    - Alternative to voice communication
  - Environmental
    - Pollutants: taxiing at airports using main engines results in emissions of around 18 million tons of CO2 per year.
  - Economic: taxiing at airports using main engines is forecast to cost airlines around $7 billion in fuel cost (2012)
    - Fuel burn
    - Inefficient engine operations in idle setting
    - Break wear increase during stop and go taxiing
    - Risk of foreign object damage due to engine suction

Future Taxi Concepts Under Discussion

- 3 main engines-off concepts:
  - Operational Towing
  - TaxiBot
  - Electric Taxi
- *"Airbus and IAI to develop pilot-controlled, semi-robotic aircraft tow tractor to allow engines-off taxiing"*
- *"Lufthansa signs electric tractor development contract to extend its green ground handling program"*
- *"The greening of airport aprons and taxiways gathers pace as industry and airlines seek new ways to reduce engine power"*
- *"Alitalia becomes launch customer for WheelTug's innovative aircraft taxiing electric drive system"*
- *EasyJet becomes first airline to join with Safran and Honeywell on development of electric green taxiing system"*
- **None of these taxi concepts consider *autonomous* engines-off taxiing.**
- **That's the goal of this project.**

Tug Autonomy Scenario



NORTHROP GRUMMAN PROPRIETARY LEVEL I

Overview of Technical Approach

- Multi-disciplinary approach
  - "We provide logistics, not autonomy"
  - HMI, Automation, Autonomy
- Performance metrics to be studied
  - Safety
  - Operator Workload
    - Ramp, tower controllers
    - Pilot, gate ground crew
  - Efficiency
    - Impact on capacity
  - Cost of maintaining fleet of tugs vs. fuel/aircraft maintenance
  - Environmental impact (noise, emissions)
- Fast time simulation using realistic airport model (DFW)
- Flexible architecture – evolutionary infusion strategy with successive levels of implementation

Tug Requirements

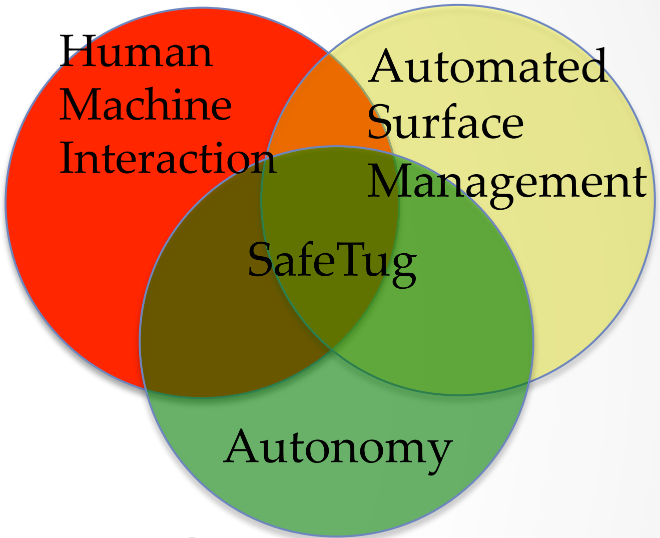
- Safe
  - Does not run into obstacles
  - Does not endanger humans
- Minimum impact
  - Seamless part of logistics; humans don't need to change their behavior (much), but can see benefits.
- Minimal changes to infrastructure
  - Don't need to re-design whole facility; can adapt to any existing facility.
- Improves surface logistics ("intra-logistics")
  - Makes humans more effective in their jobs
  - "We're not supplying tugs, we're supplying logistics".

Challenges

- Technical challenges:
  - Accommodate large unpredictable variation in the environment,
  - Accommodate real time variation in the environment,
  - Achieve customer-acceptable reliability levels,
  - Provide intrinsic safety of use and operation.
- Economic challenges:
  - Required affordability (ideally, payback within twelve months),
  - No external hidden costs to the customer,
  - Provide a robust business model.
- Social challenges:
  - If a labor replacement is involved, then the product must provide an equivalent or greater benefit to some portion of the labor pool to offset the potential job loss,
  - Must operate in a way that feels common and familiar, not foreign,
  - Must operate in a way that is perceived as completely safe,
  - Must operate in a way that is perceived as simple and not intimidating.

SafeTug Architecture

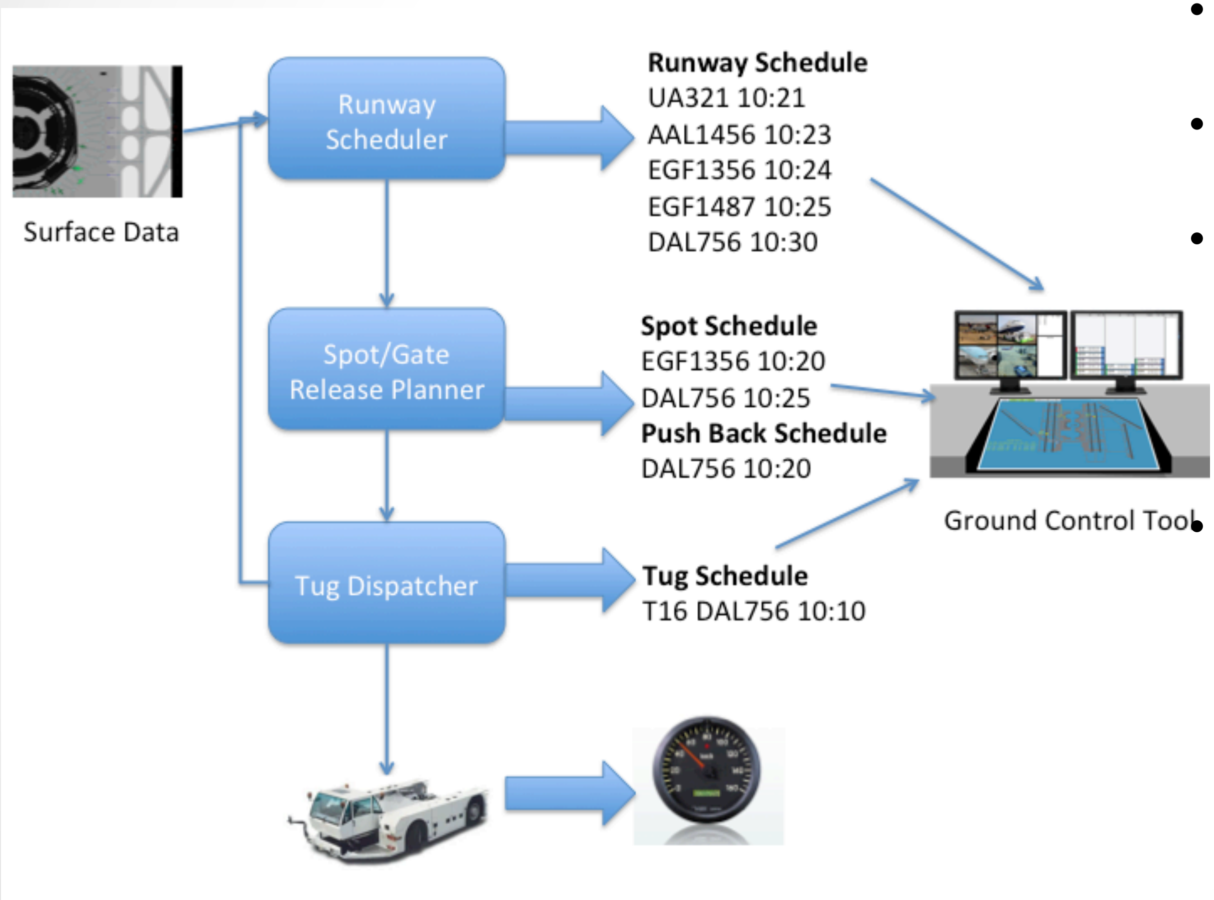
- Automated surface management
  - Augmenting capabilities for automated route planning and scheduling and intelligent advice to controllers.
- Human Machine Interaction
  - Technical focus on calibrated trust, Situational Awareness (SA) and mental workload in a tug-based taxi system.
- Autonomy
  - Trade studies of information flow necessary to make the appropriate decisions to maintain safe and successful navigation within the terminal area, identify requirements for sensor output and performance, and provide selection criteria for algorithms.



Surface Planning and Scheduling Problem

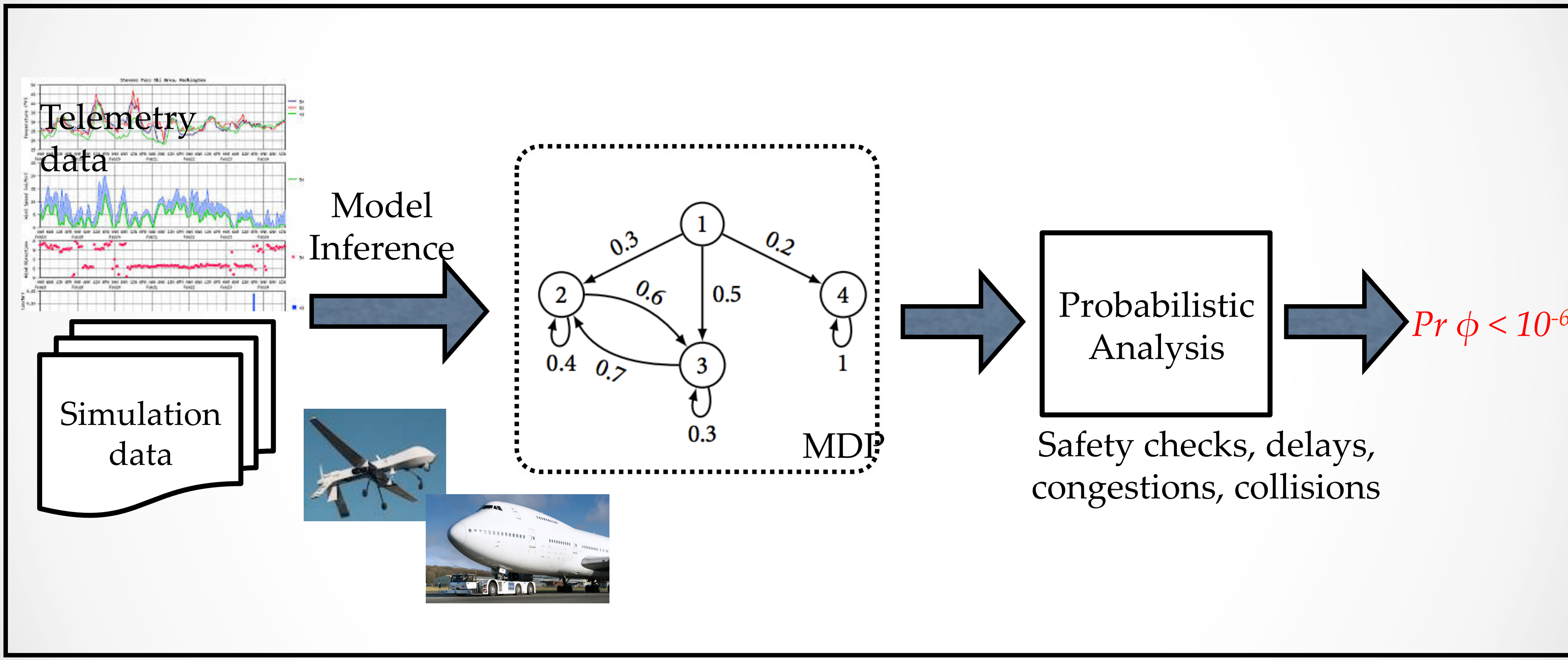
- Optimization of airport surface operations can be classified into the following sub-problems:
  - runway sequencing and scheduling (Rathinam et. al, 2009);
  - spot or gate release scheduling (Malik, Gupta and Jung 2012);
  - gate allocation (Cheng, Sharma and Foyle 2001) and
  - taxi route planning and scheduling (Visser and Roland 2003).
- Surface movement optimization is NP-hard (Reif 1979).
- Several types of constraints are involved, including push-back times, taxiway layouts, and runway and taxi-way separation.
- Planning is dynamic, with aircraft continuously entering and leaving the planning space, and replete with uncertainty and unexpected events.
- These complexities and the dynamic nature of the environment motivate approaches to automated planning that require reduced computational overhead while achieving useful results.

Spot and Runway Advisor (SARDA)



- Graphical representation of airport surface.
- Shortest path routes pre-determined.
- Three main components: runway sequencer and scheduler; spot and gate push-back scheduler; and tug dispatcher.
- 10-second scheduling cycle to deal with changing environment and uncertainty.
    - Assumes detailed surface surveillance data using ASDE-X

Predictive Analysis For Safe Surface and Air Operations

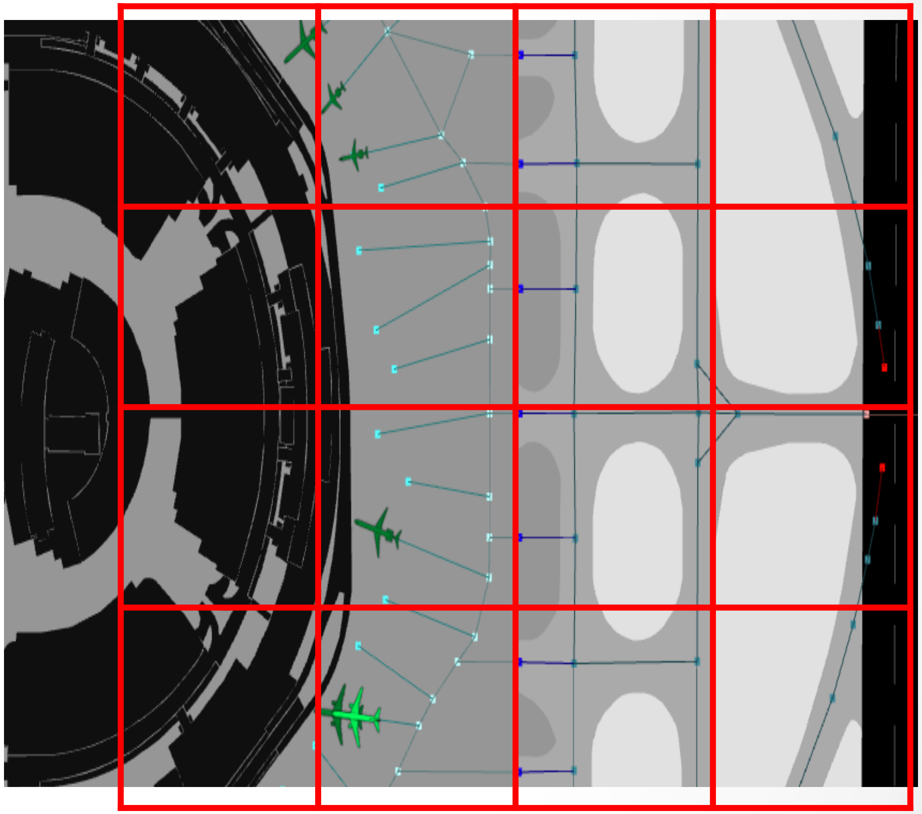


Model inference

- Inference of Discrete-Time Markov Chain (DTMC)
  - automata labeled with outgoing probabilities on their transitions
- Logged data consists of time series
  - each step encodes the value of the states observed at each time step.
- States and transitions of DTMC
  - States are "abstractions" of state reported in the log file
  - Transitions are time steps in the log file
  - "abstraction" defined by the user; depends on properties of interest
- Probability distribution for a particular state *s*
  - estimated by computing the ratio between the number of traversals for each outgoing transition and the total number of traversals of the transitions exiting state *s*
  - corresponds to the *maximum likelihood estimator* for the probability distribution at that state
- Prototype implementation in Java

Grid Abstraction

- "Grid" abstraction
- Divide airport surface in a grid
- Keep "count" of vehicles (airplanes, tugs) in each grid
- Initial results:
  - 1 square, keeps the counts of airplanes on the surface: 36 states, Max delay: 10792.0 (see also attached generated model)
  - 4 squares: 51 states



Next steps

- Distinguish between arrivals/departures
- Get log file with tugs
- Create a more detailed model with a finer grid
- Use random testing to bootstrap the learning
- Integrate model into tug dispatcher
  - Minimize delays in taxing
  - Avoid congestions

Human Machine Interface (HMI)

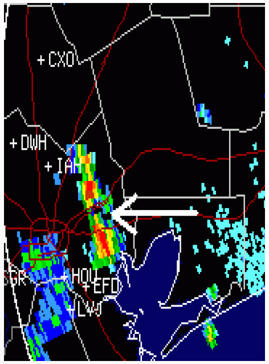
- Goal: Assist ATC, Ramp Control and Pilots in maintaining Situational Awareness, Workload and Trust in the SAFETug System
- ATC/Ramp control are the primary users, performing a supervisory role
  - Monitor multiple tugs as they progress throughout the airport
  - Confirm/Modify taxiing instructions supplied to tugs by the SAFETug system
  - Directly intercede when the probability of failure (e.g., a runway incursion) is high
- Pilot – continuous supervision of tug, and environment
  - Understand tug taxiing route
  - Maintain awareness of the tug and the environment around the tug
  - Be able to predict the tug's behavior
  - Emergency access to tug navigation e.g. stopping the tug

Understanding the Airport Operations Area

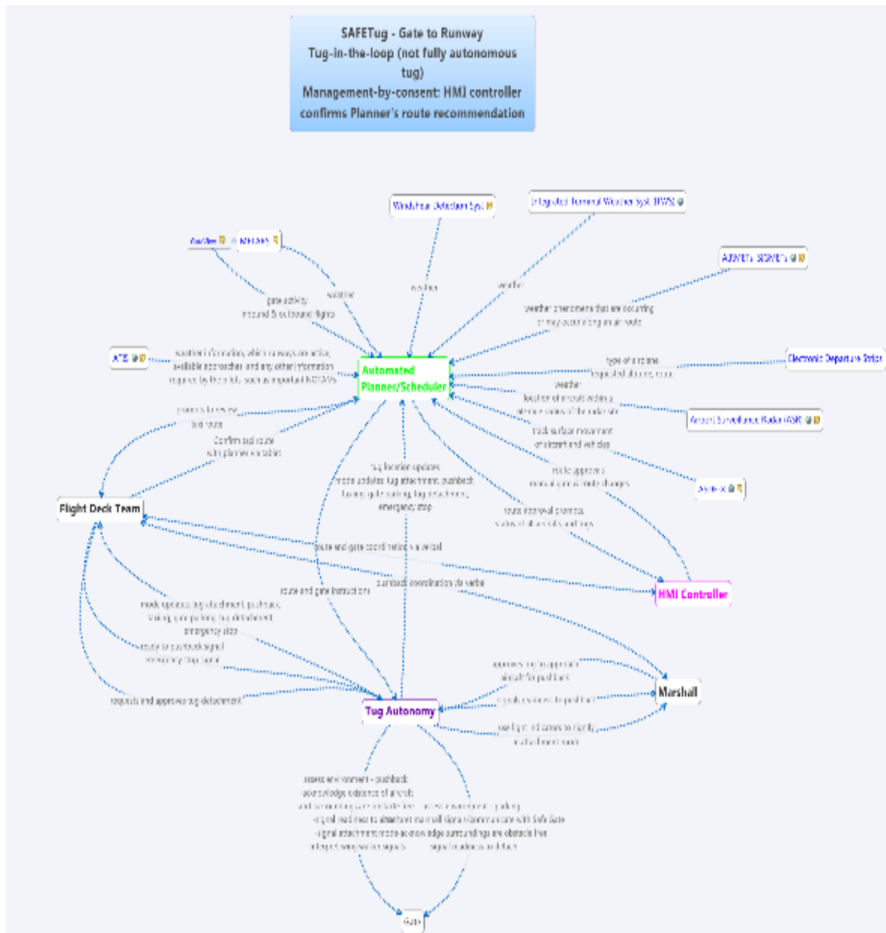
- First task: understand the Airport Operations Area (AOA)
- This was accomplished by visiting
  - Air Traffic Control Towers at Hobby (HOU) and at Bush Intercontinental Airport (IAH)
  - United Airlines Ramp Control at IAH
  - Southwest Airlines Ground Operations at HOU
- The team also performed structured and unstructured pilot interviews

Site Visits and Interviews

- Discussed Roles and Responsibilities
    - Ramp manages vehicles around the ramp area
    - ATC manages taxi, runways, local airspace and sometimes ramp area
    - Handoff occurs at the zipper line
- Learned about equipment and technology
- Discussed how SA was maintained for ground traffic
    - Visual and Communication
    - Data Strips placement and orientation
    - ASDE-X
- General questions on trusting technological tools and of using the SAFETug system



Adding SAFETug into Current System



HMI Ecological Interface Design

- Ecological Interface Design (EID) – A framework for designing interfaces for complex human-machine systems
  - Work Domain Analysis (WDA) – searches for the information on how the environment works regardless of the task and begins with creating an abstraction hierarchy
  - Skills, Rules Knowledge (SRK) framework - Reduce cognitive burden of the operators
    - Skill-based behavior (SBB) - to support interaction via time-space signals by allowing the user to act directly on the display.
    - Rule-based behavior (RBB) - provide a consistent one-to-one mapping between the work domain constraints and the cues provided by the interface.
    - Knowledge-based behavior (KBB) - represent the work domain in the form of an abstraction hierarchy to serve as an externalized mental model that will support problem solving.
  - Combining WDA and SRK allows an EID based HMI to improve SA and reduce mental workload while supporting knowledge-based reasoning for expected and unexpected events
- Task Analysis (TA)
  - Focus is on activities/actions necessary to complete a known goal
  - Used to validate the WDA

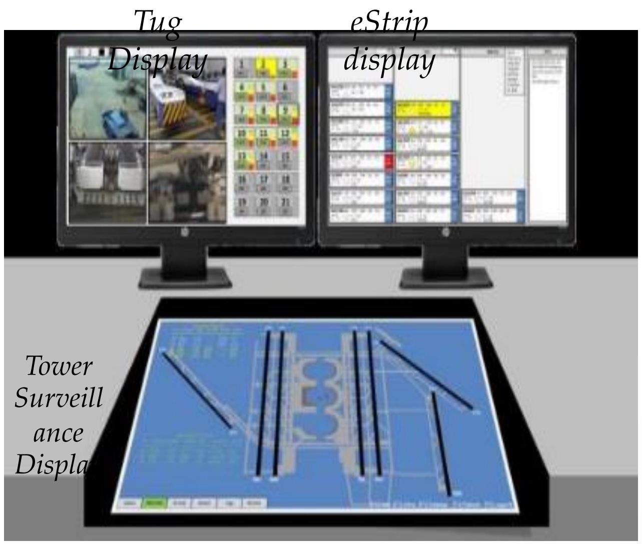
Keeping it Simple Design Goals

- Build upon already existing systems and layouts
- Use familiar interface elements
- Keep layout purposeful
- Strategically use color
- Use typography to create hierarchy and clarity
- Make sure the system communicates current status appropriately and without confusion (contradiction)

SAFETug Workstation

- Conceptual design for Pilot and ATC/Ramp
- Goal: Minimize changes to current operations

Pilot HMI Design



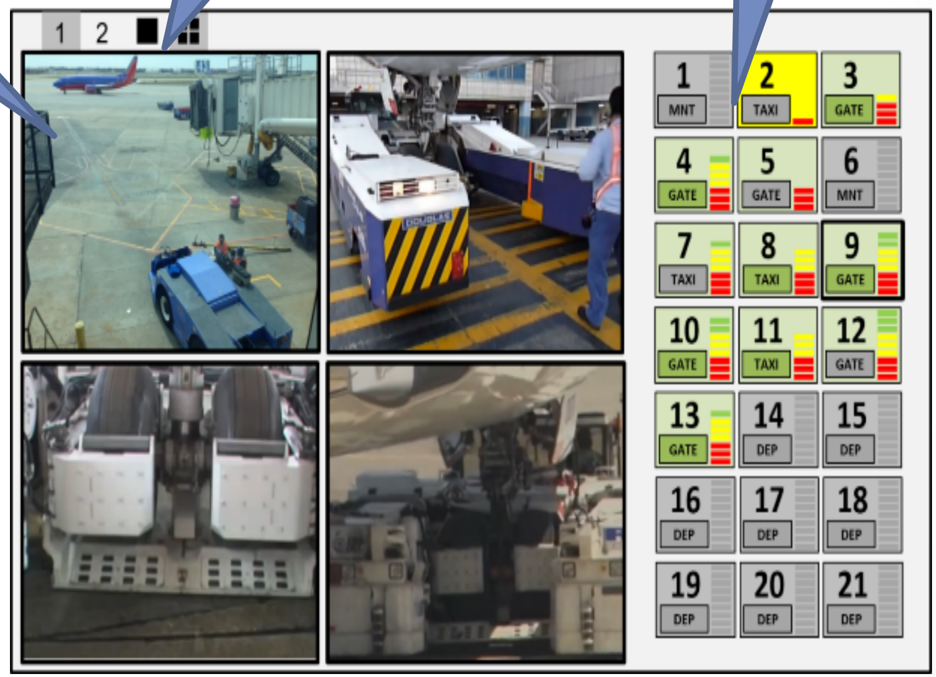
Conceptual design of SAFETug workstation for ATC/Ramp control

Tug Display

Live camera feed of selected tugs (if available)

Switch between multiple or single camera

Tug status indicator e.g. status, location, power, attached/ detached



NASA Aeronautics Research Institute

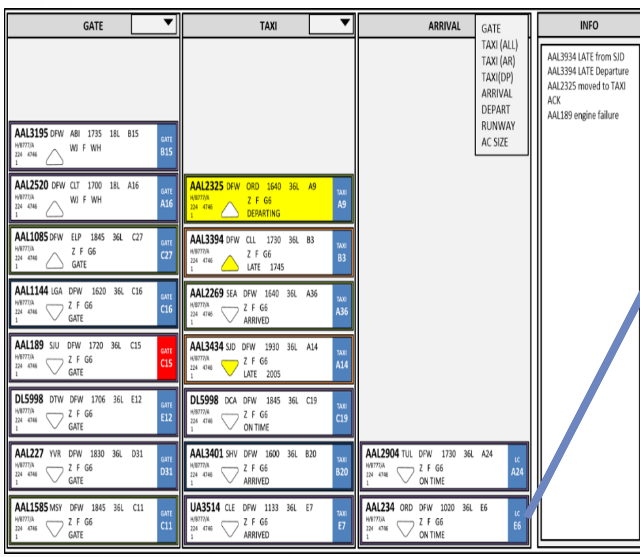
Lockheed Martin

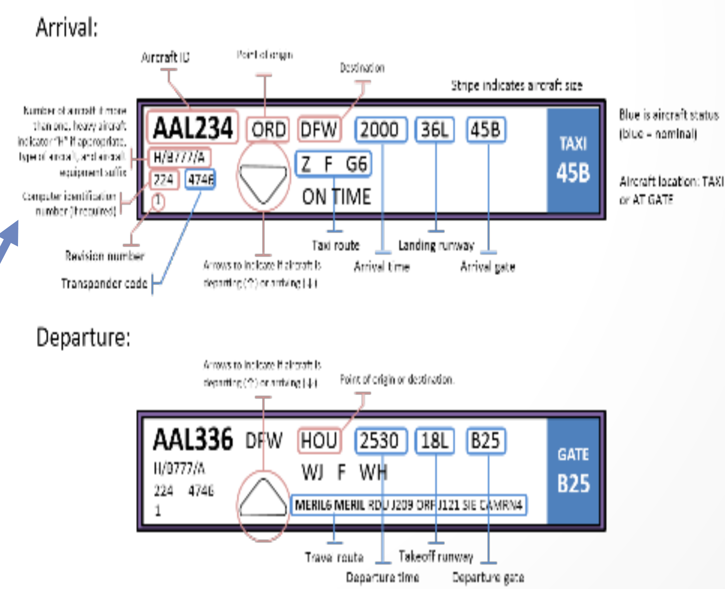
Ames Research Center

Human Health and Performance

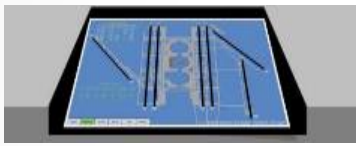
Ames UCSC UARC University Affiliated Research Center

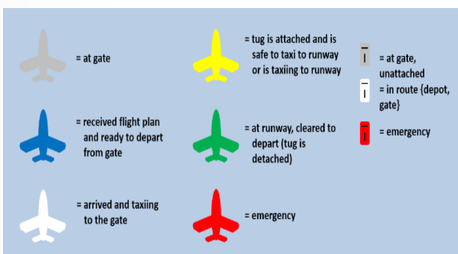
eStrip Display

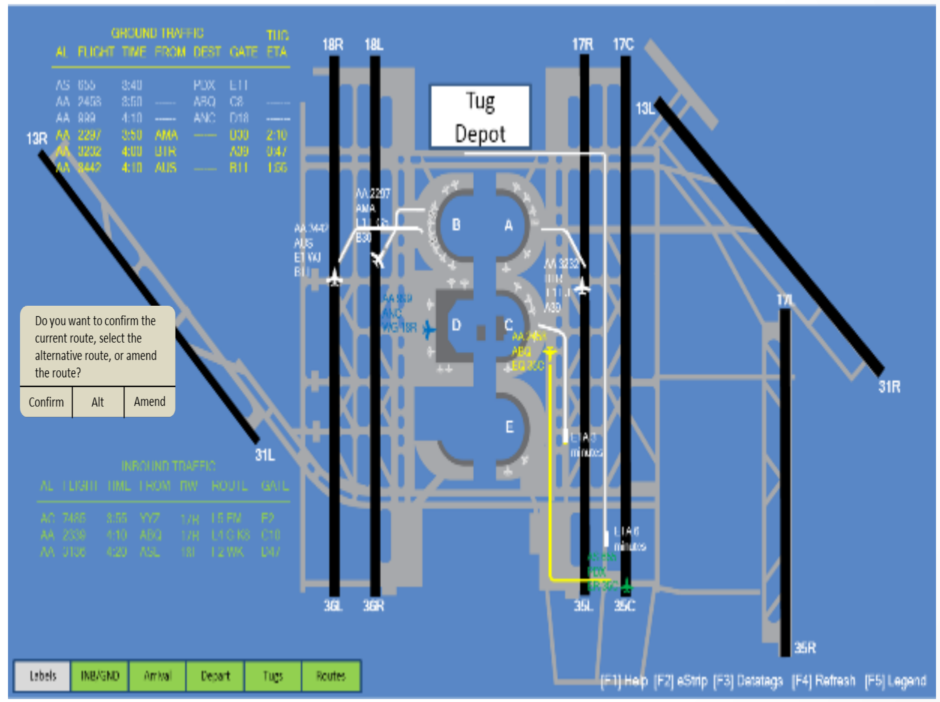




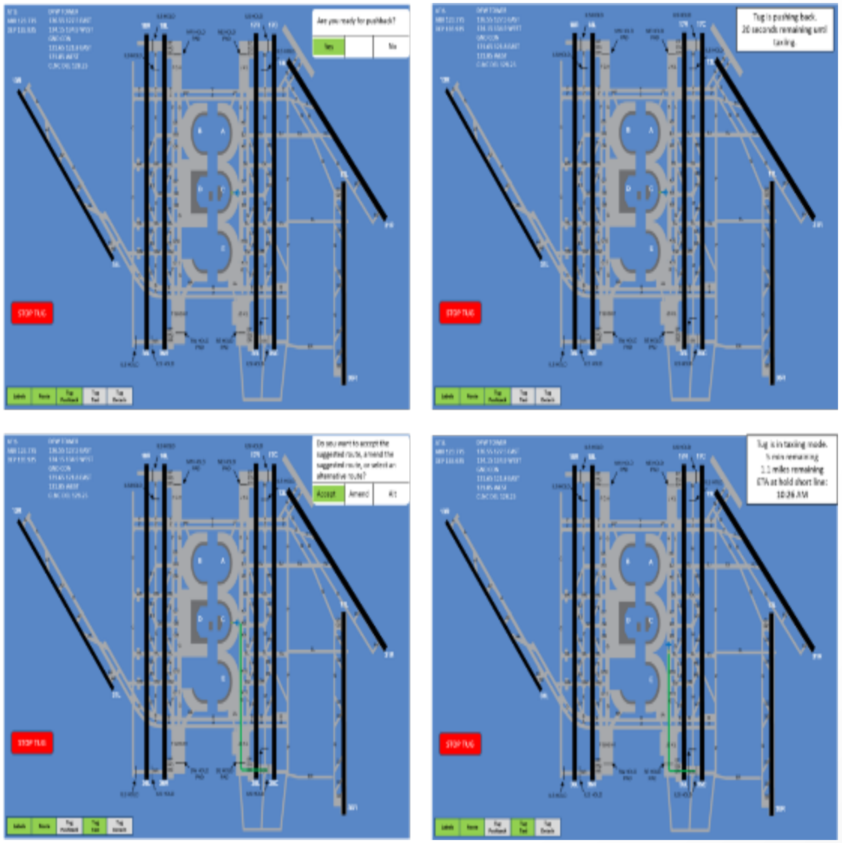
Initial Tower Surveillance Display







Initial Pilot Display

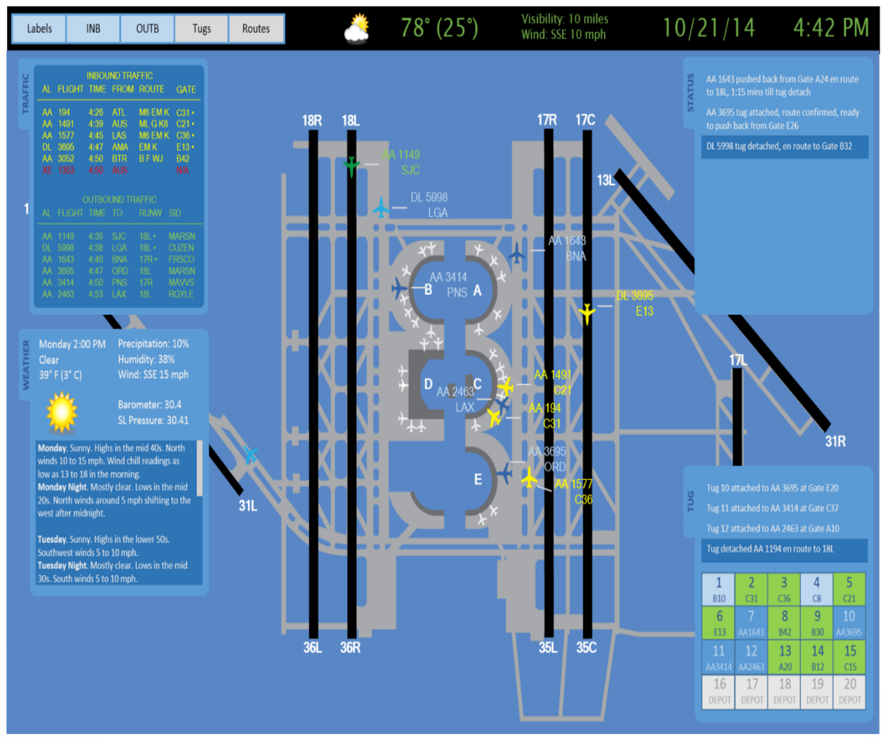


HMI Heursitic Evaluations

- Changed wording and abbreviations
- Use time instead of distance to better facilitate ETA
- Show taxiing path designations for easier read back to ATC
- Clearly show tug detachment point
- Zoom pilot display to be route focused
- Modify location of buttons and popups
- Provide an accept button for route
- Show to pilot a stop button only when tug is attached
- Add a detach option

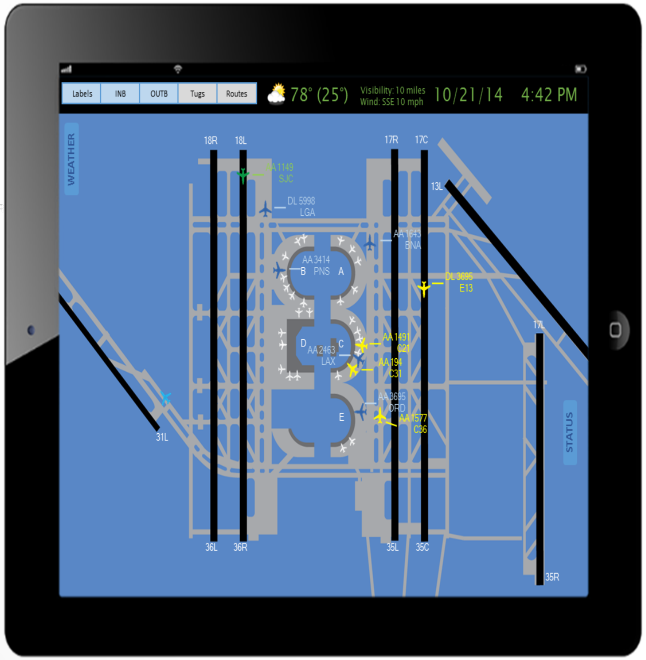
Final TSD Evaluation

- TSD used for final heuristic evaluations



Final Pilot Evaluation

- Pilot display used for final heuristic evaluations



SA, Workload, and Trust

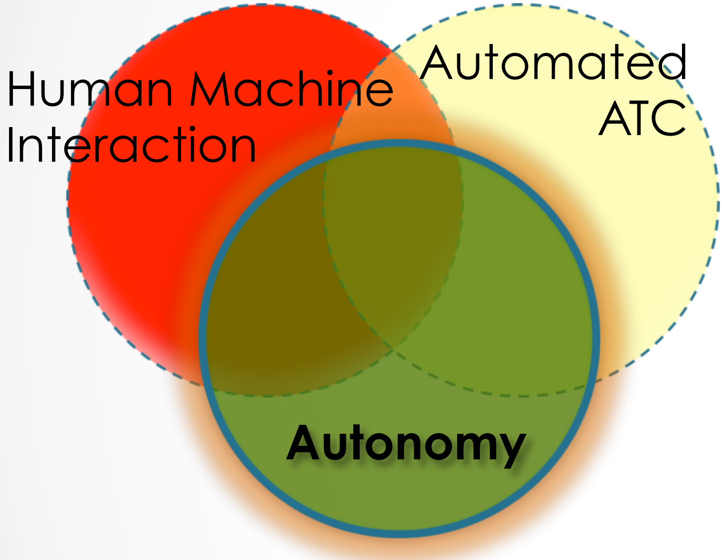
- How does the HMI assist in maintaining Situational Awareness, Workload and Trust in the SAFETug System
    - Support the creation of a human/system symbiosis by making SAFETug a decision support aid
    - Minimize changes to current operations
    - Provide SA support instead of decision by showing route, weather and flight information
    - Modify amount of automation – Human in the loop vs. Human on the loop
    - Avoid advance queuing of task by making a single prompt visible
    - Provide visual route information
    - Provide ETA
    - Use automation to carry out routine actions e.g. route planning and taxiing.
    - Ease of Use by building upon existing ASDE-X
    - Provide status displays to keep the operator in the loop
    - Operator remains in control by making routes suggestions only

HMI Year 1 Accomplishments

- Work Domain Analysis of Airport Operations Area
- Task Analysis of ATC Tower and Ramp control
- Conceptual Design of SAFETug HMI Workstation and Pilot HMI
- Heuristic Evaluation on Tower Surveillance Display and Pilot HMI
- Low Fidelity Prototype of Tower Surveillance Display

SAFETug:

Autonomy System Design / Trades



Chris Garrett

LM ATL Intelligent Robotics Lab

robert.c.garrett@lmco.com

Updated 1/9/2015

Host Tug Autonomy Trade

These options represent the best approach given our current understanding of the Host Tug and System Requirements

- **Autonomy**
  - High-Level Autonomy Requirements
  - Exemplar Host Tug Description
  - Applique Components / Architecture
- **Sensors**
  - Configuration / Emplacement Trades
  - Data Collection / Analysis
- **Perception**
  - Software Architecture
  - Hardware Requirements
- **Safety**
  - Obstacle & Threat Avoidance
  - Contingency Management

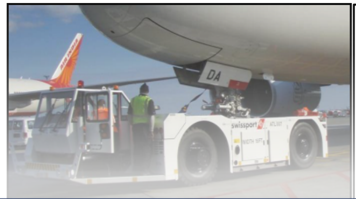
Requirements Drivers

- **Safety**
  - Human – Autonomous Tug must be safe to operate near people
  - Equipment – Autonomous Tug must not pose a physical (mechanical, electrical, etc.) threat to infrastructure, vehicles, etc.
  - Continuity– Autonomous Tug must not be disruptive to existing procedures for ground operations
- **Cost**
  - Up-Front – Applique must not have a high cost of entry
  - Recurring – Applique must not be financially burdensome over time
  - Reversibility – Applique must be able to be completely removed and tug restored to normal manual operability
- **Effectiveness**
  - Logistics Improvement – Measurable positive impact to logistics
  - Cost Improvement – Measurable reduction in cost related to fuel consumption by aircraft while on the ground

Host Tug: Expediter 600 (Towbarless)

Control System

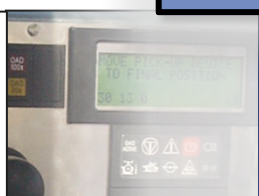
- Clean Dashboard Concept
  - Simplest controls in the industry
- Automated NLG Pick-up Sequence
  - Single joystick control and interlocks
  - Automated procedures
  - Detailed instructions on PLC screen



- Wide-Body Aircraft Pushbacks and Maintenance Tows
- Aircraft Range: A300/B767 through A380
- Top Speed: 28 km/hr (17 mph)
- Four (4) Wheel Drive, Two (2) Wheel Steer
- Power Source: Mercedes OM 502LA V8, 420 kW (563 hp)

Best Tradeoff between Capacity and Ease to Automate

- Fail Safe Proximity Switches Detect Nose Wheel Size
- Automatically Adjusts:
  - Maximum tractive effort
  - Maximum brake force
  - Oversteer Alert Device setting
- Minimizes Risk of Operator Error and Aircraft Damage



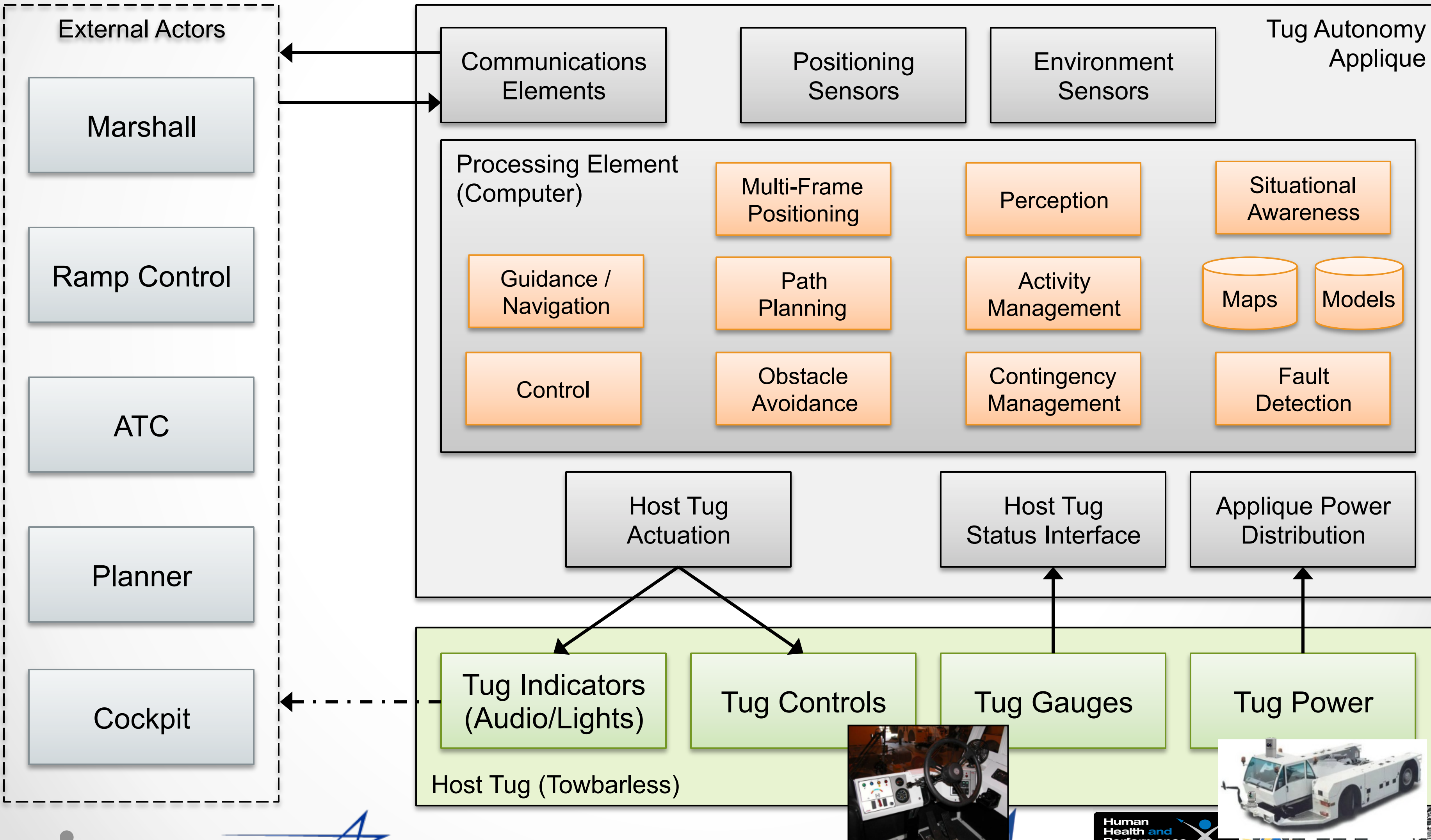
Automat
Aircraft Selectio

Operator's Cab

- Spacious Cab with Easy Access
- Excellent Visibility of NLG Pick-up and Surrounding Area
  - Elevating cab standard feature
- Dual Driving Controls
  - Rearward: Aircraft NLG pick-up, push backs
  - Forward: Maintenance towing
- Suspension Driver's Seat
  - Swivels 180°
- Well Insulated Cab
  - Low noise level
  - Tightly sealed, protects against jet blast
- Two (2) Passenger "Jump" Seats
- Optional Air Conditioning

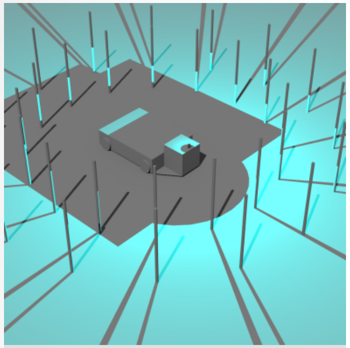
- Aircraft Landing Gear Locks Securely into the Tractor's Cradle
  - Accommodates raked NLG (6° swivel)
  - Positive top locking cylinders
  - Supports aircraft weight underneath the nose wheel
  - Interlocks prevent closing gates with the NLG partially inserted
  - Interlocks prevent completing cycle if NLG is improperly engaged
- Cradle Moves During Turns Taking Pressure Off of the Landing Gear
- Simple Design with Six (6) Hydraulic Cylinders

Applique Components

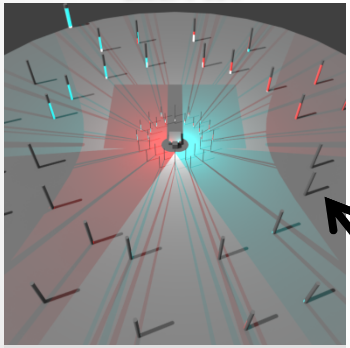


Sensors: 3D LIDAR Placement

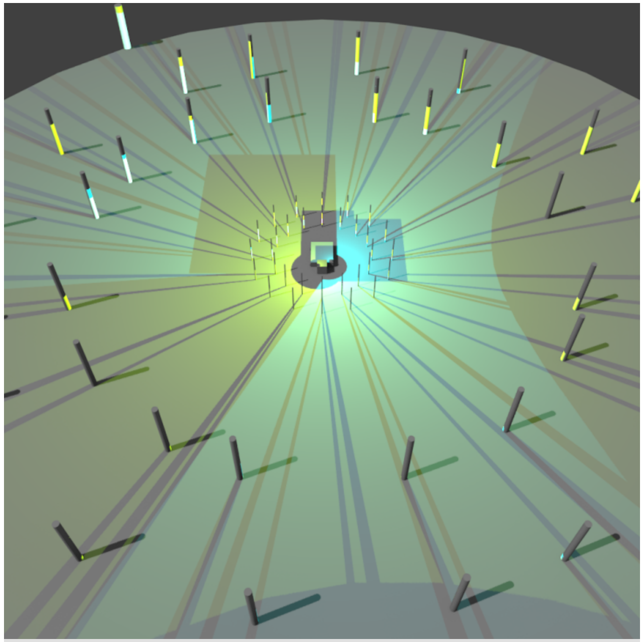
Placement trade balancing long-range, tug-proximal coverage, artifact quality, and cost.



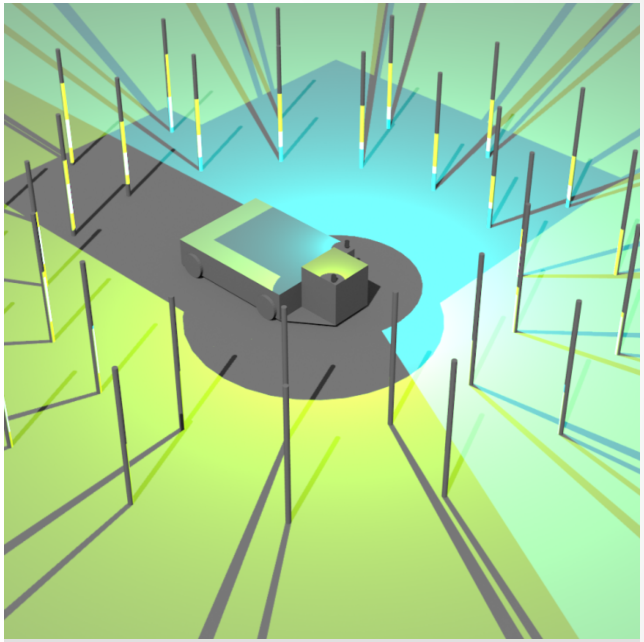
Best Single LIDAR



Balanced, 5-deg Tilt



Unbalanced, Multi-Axis Tilt (Area)

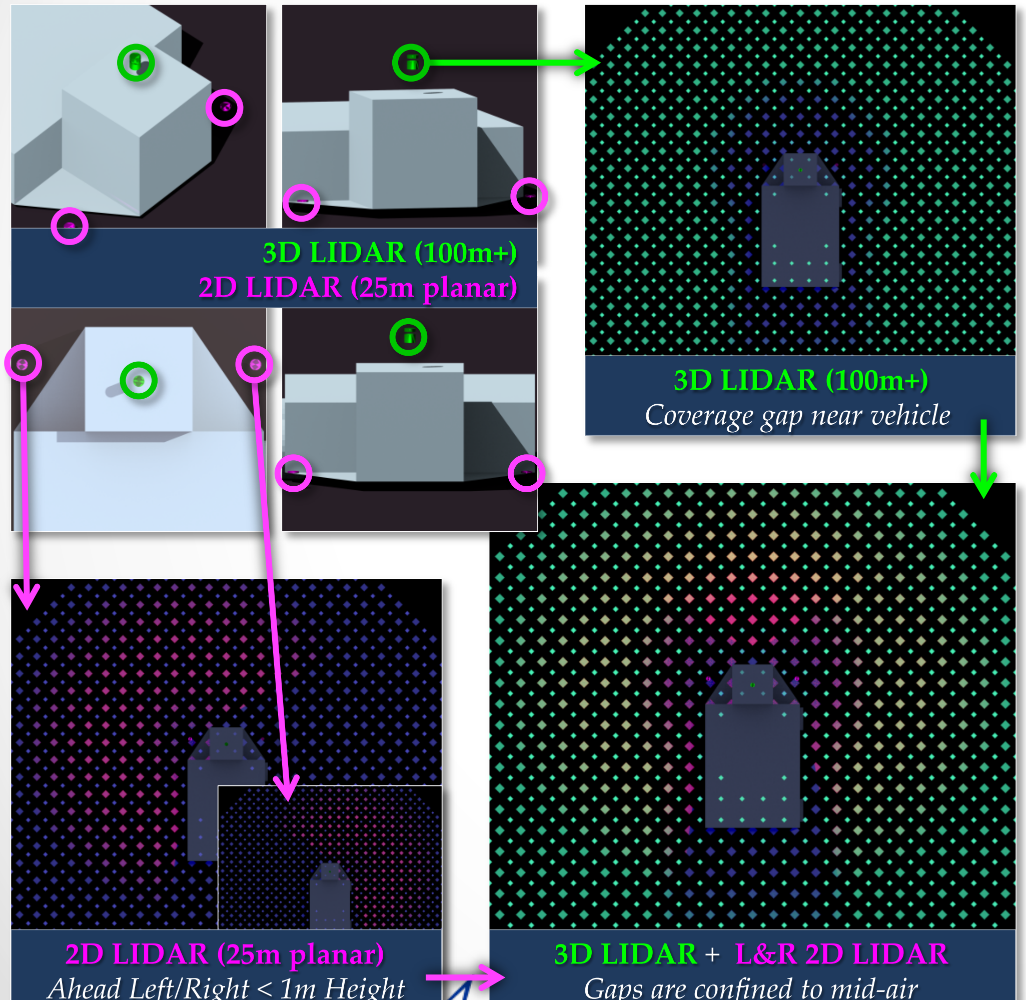


Unbalanced, Multi-Axis Tilt (Zoom)

- Single LIDAR coverage: unacceptable near tug
- Two-LIDAR best balanced coverage: gaps starting ~40m out due to shadowing
- Two-LIDAR unbalanced coverage: best, but still not seeing ground at up to ~6m from tug center (~2-3m from tug body)

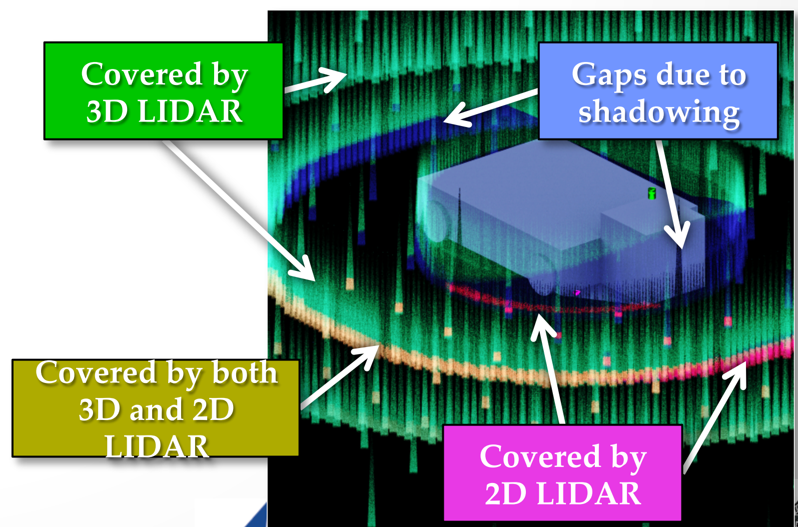
Sensors: 3D/2D LIDAR Placement

Placement trade balancing long-range, tug-proximal coverage, artifact quality, and cost.



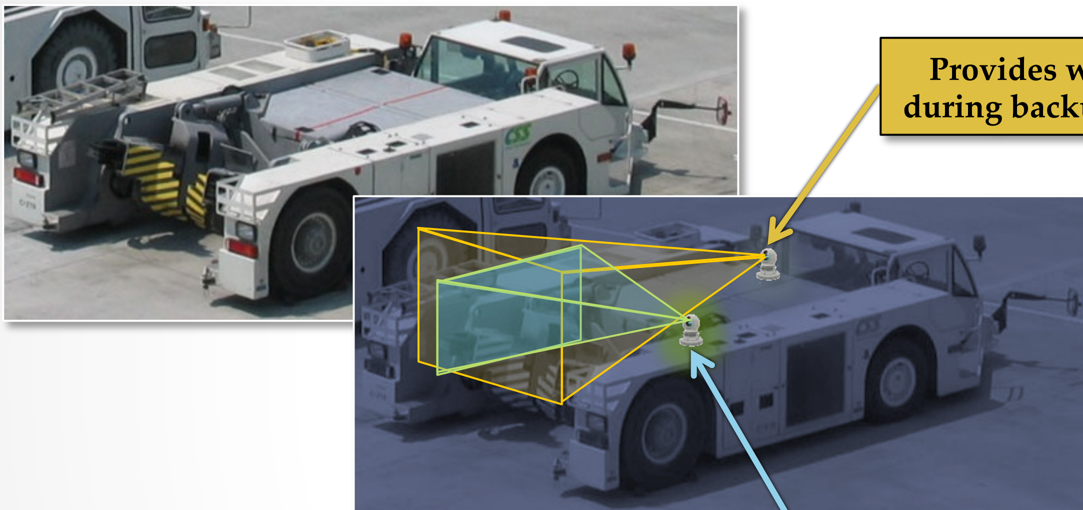
- Use single 3D LIDAR for area coverage
- Fill in the gaps near the vehicle with 2D planar LIDAR(s), which are often less expensive
- LIDARs can be extended from the vehicle, but not impact its ability to navigate through its areas of operation

- Gaps near are due to shadowing /occlusion of the LIDARs by the tug body
- Gaps must be smaller than a human or present no danger to humans during normal operation



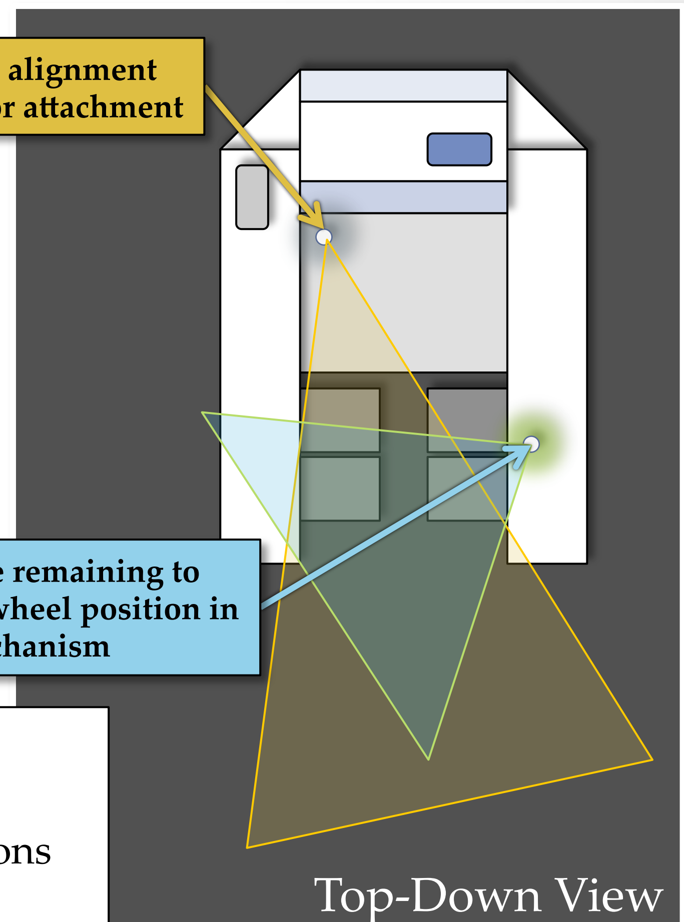
Sensors: EO/IR Camera Placement

Placement trade balancing long-range, tug-proximal coverage, artifact quality, and cost.



Provides wheel alignment during backup for attachment

Provides distance remaining to wheel and verifies wheel position in the lift mechanism

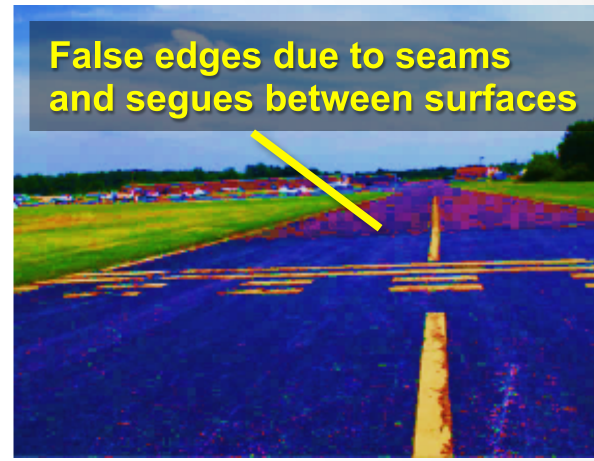


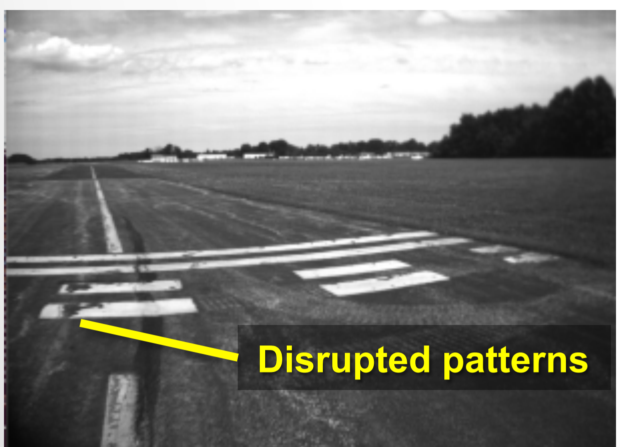
- Backup camera on opposite side from normal tug operation
- Cross-view camera provides better estimation of distance remaining
- Cross-view can be matched to known acceptable wheel positions prior to activating lift
- Both cameras can be used for tracking IR signatures to provide coverage in LIDAR shadows of human activity

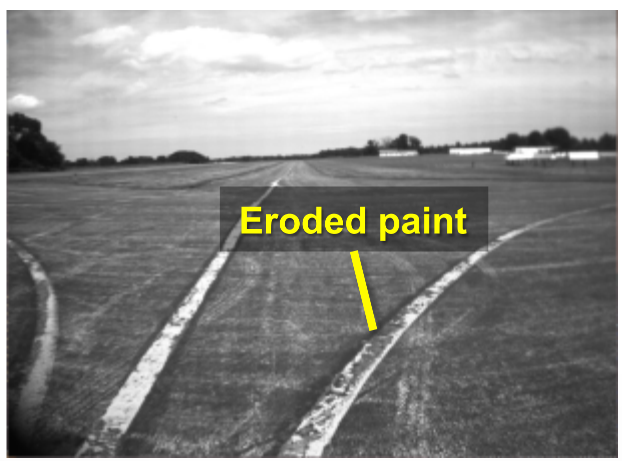
Camera Data Collection & Analysis

EO/IR data collection at South Jersey Regional Airport (VAY)

- **Manned navigation of taxi and runways to collect EO data**
- **Captures many of the perception challenges that are easy for humans, more difficult for automated perception algorithms**
- **Many challenges can be mitigated through correlation / fusion with prior map and with LIDAR data**

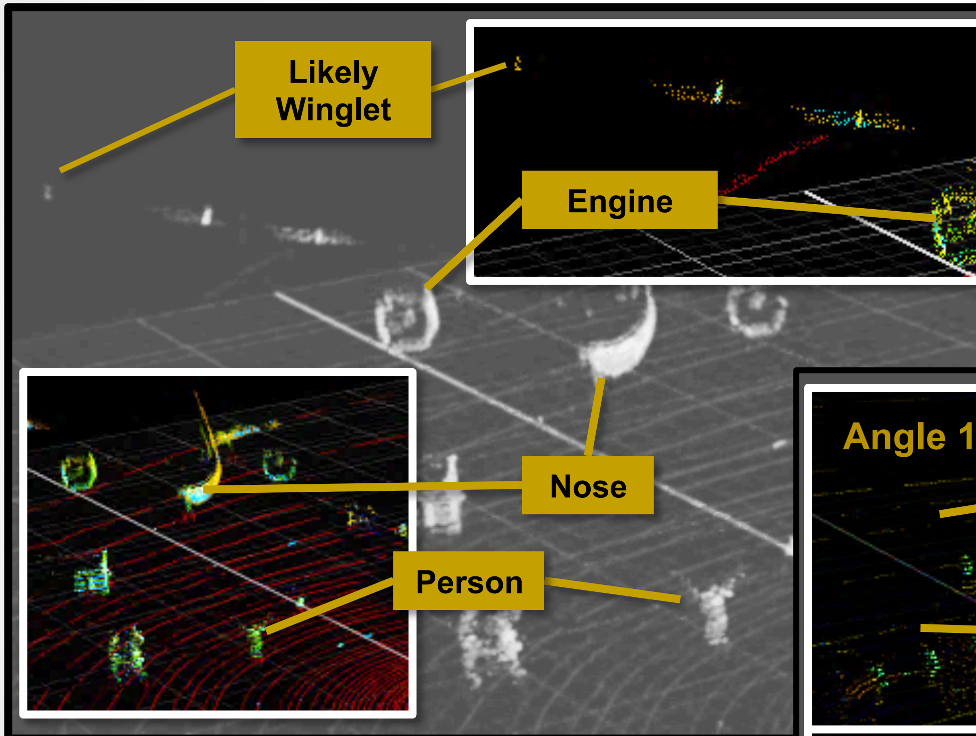






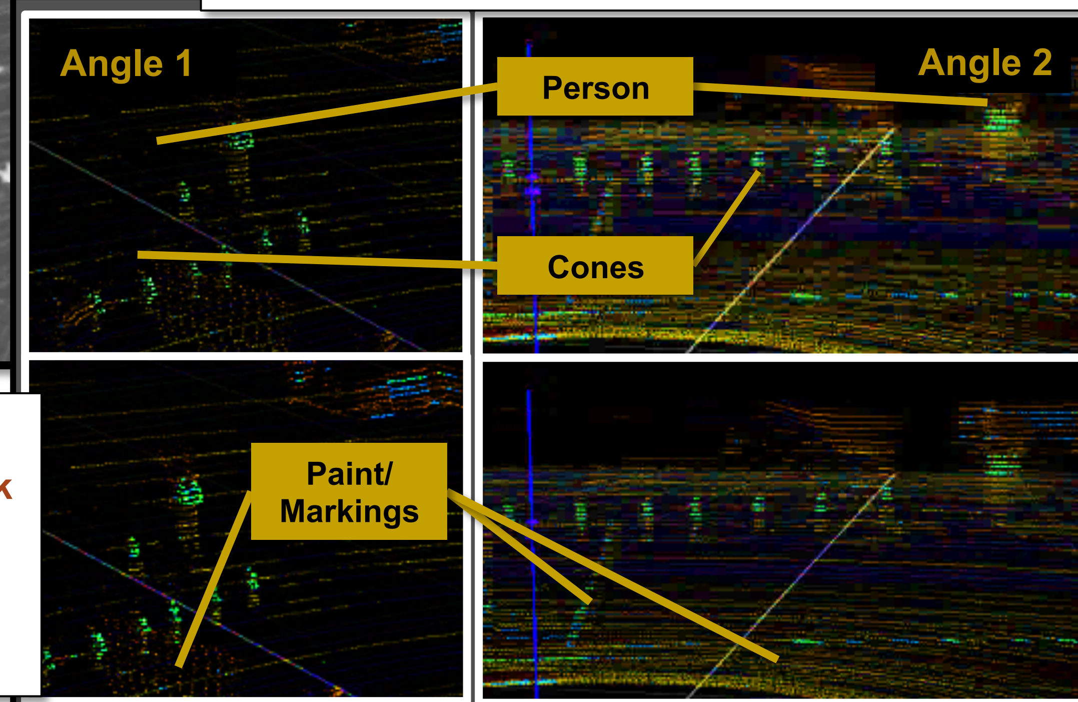
LIDAR Data Collection & Analysis

LIDAR data collection at Atlantic City International Airport (ACY)



RANSAC-based (Random Sampling and Consensus) algorithms can be used for:

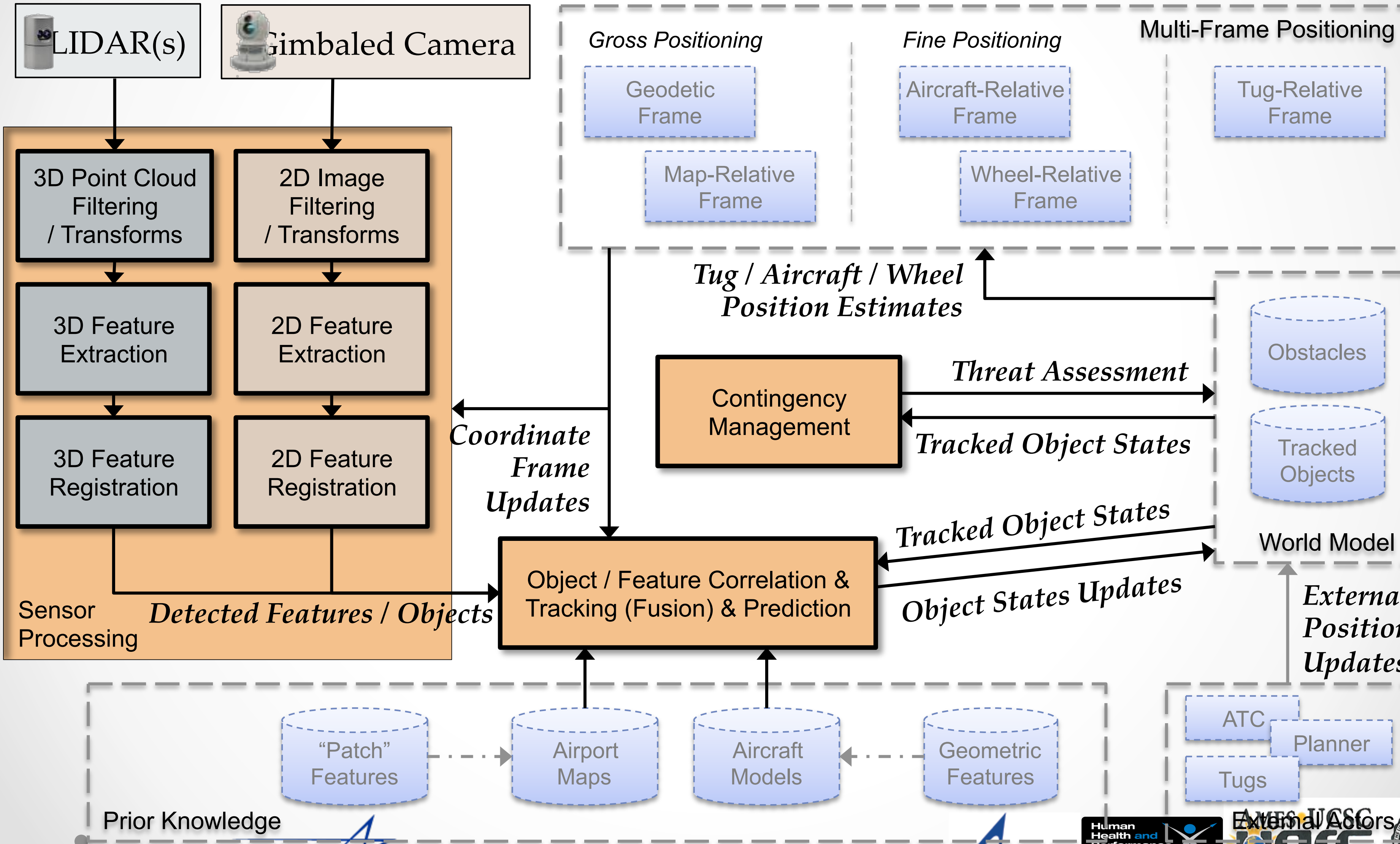
- **Template-based matching of geometric shapes (pieces of plane, cones, etc.)**
- **Ground plane / tarmac extraction**
- **Line extraction (RANSAC or Hough)**



Two key finds:

- **Reflective vests make easy targets to track**
- **Identifying painted markers (patches) in the LIDAR can be detected and tracked to aid in localization and navigation**

Perception: Software Architecture



Perception: SW/Algorithms

2D EO/IR Video

- Edge detection (Canny or similar)
- Line/Curve detection
- Ground plane registration
- Affine transform from ground plane
- Fourier transform + pattern match
- IR-band filtering / blob tracking
- Segmentation
- Feature matching / image recognition (wheels, nose, etc.)
- Distance estimation

Tracking / Fusion

- 2D object tracking / registration
- 3D object tracking / registration
- Multi-lateration / correlation (2D → 3D track conversion)
- Multi-source track correlation
- Track prediction

3D LIDAR Point Cloud

- RANSAC – Geometric primitive matching
- RANSAC – Map/model alignment/ registration
- Reflectivity filtering
- Ground plane extraction (likely RANSAC)
- Fourier transform + pattern match (on ground plane)
- Segmentation + Noise Filtering

Navigation / Contingency / Other

- Maintenance of navigation frame transforms (tug-relative ←→ geodetic, etc.)
- Obstacle detection
- Obstacle threat assessment
- Anomaly detection (bad wheel positioning, etc.)

SW Packages

- OpenCV
- Point Cloud Library (PCL)
- LM-ATL's Track Fusion
- OpenNI (optional)

Perception: Processing Requirements

<u>2D EO/IR Load Drivers:</u>
- Feature Matching / Object Recognition

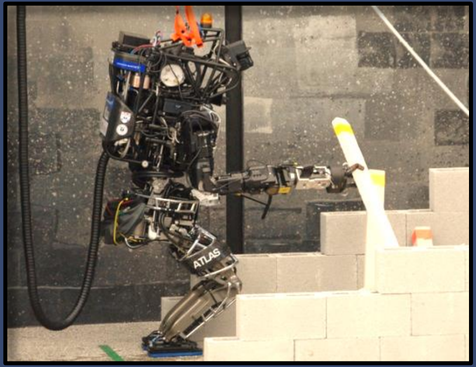
<u>3D LIDAR Load Drivers:</u>
- Ground Plane Registration
- Geometric Matching
- 3D Object Registration

<u>Tracking Load Drivers:</u>
- Multi-Source Track Correlation

<u>Nav. / Contingency / Other Load Drivers:</u>
- Obstacle Threat Assessment
- Anomaly Detection

Relative Processing Load
- Highest Load
- High Load
- Moderate Load

Similar Functionality Performed on DARPA Robotic Challenge (TROOPER)
- LIDAR processed at 1/3.14 = ~0.32 Hz
- Stereo Camera processed at 20Hz

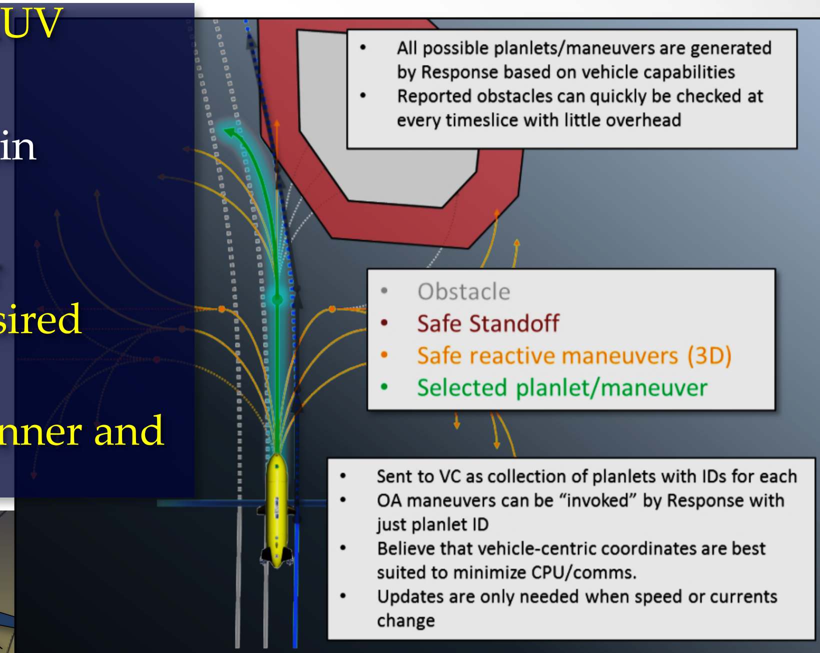


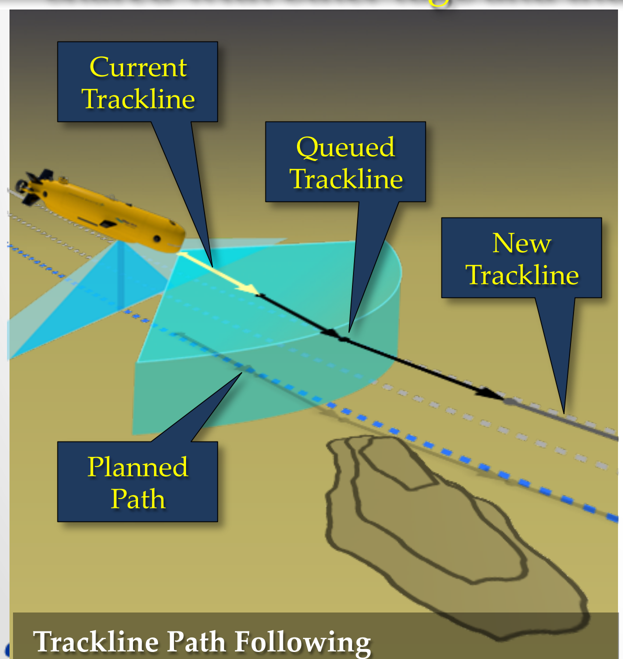
Laptop Configuration (Dell Precision M4800)
- Processor: Intel Core i7-4900MQ CPU @ 2.80GHz × 8
- Memory: 32 GB
- Graphics: NVidia Quadro K2100M

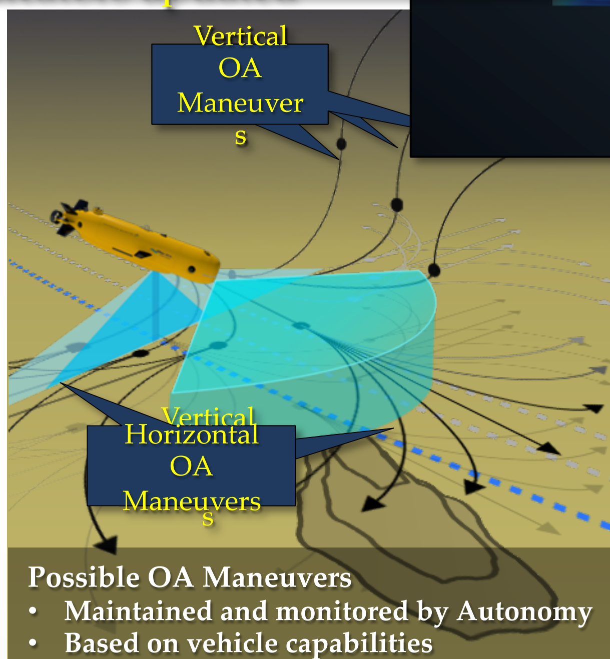
** Note further improvements can be made by utilizing the GPU*

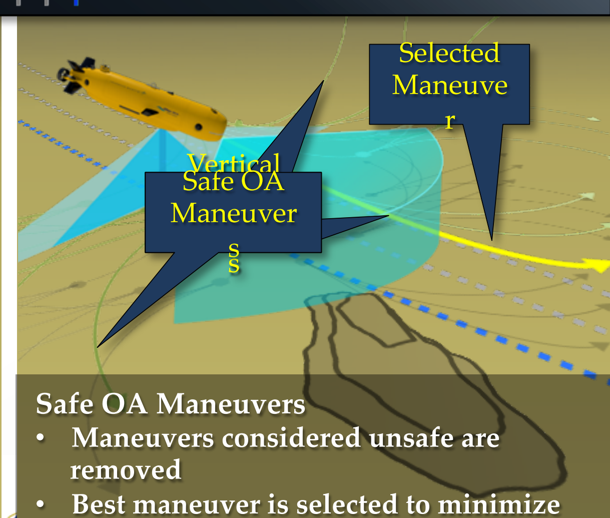
Safety: Obstacle / Threat Avoidance

- Obstacle / Threat Avoidance similar to LM Marlin AUV
  - Braking, especially during towing, not easy
  - Nominal speed of the Tug roughly 5x that of Marlin
  - Sensor range of Tug > 5x of the Marlin
- Long plan segments will be subdivided into smaller tracklines as needed to minimize deviation from desired path from the Planner
- Avoidance behaviors communicated back to the planner and shared with other tugs and indicators updated





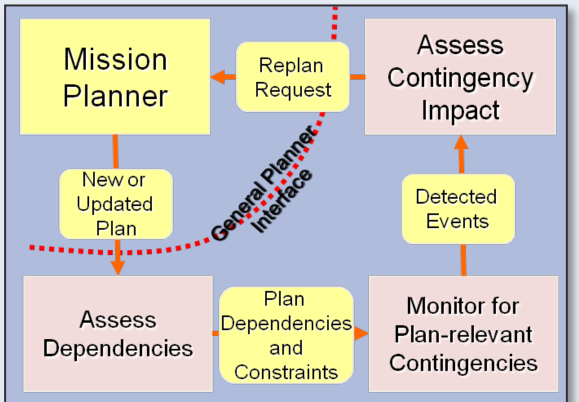




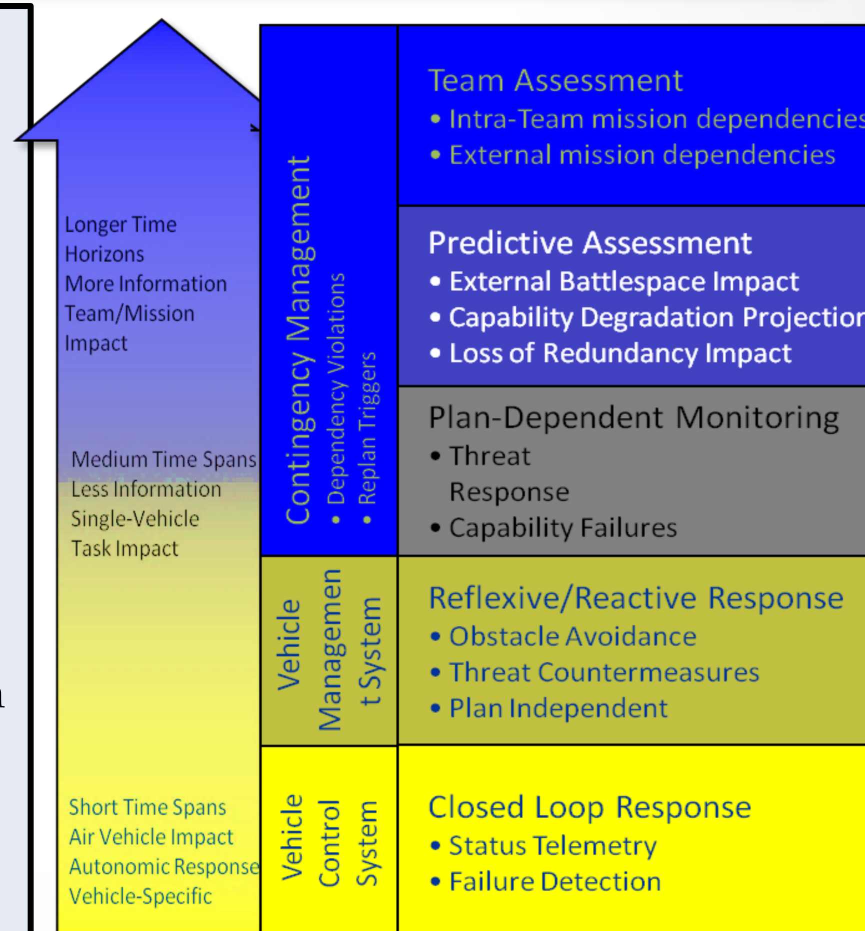
Safety: Contingency Management

Effective Contingency Management increases reliability and robustness of unmanned systems and reduces human workload

MENSA:
Mission Effectiveness & Safety Assessment

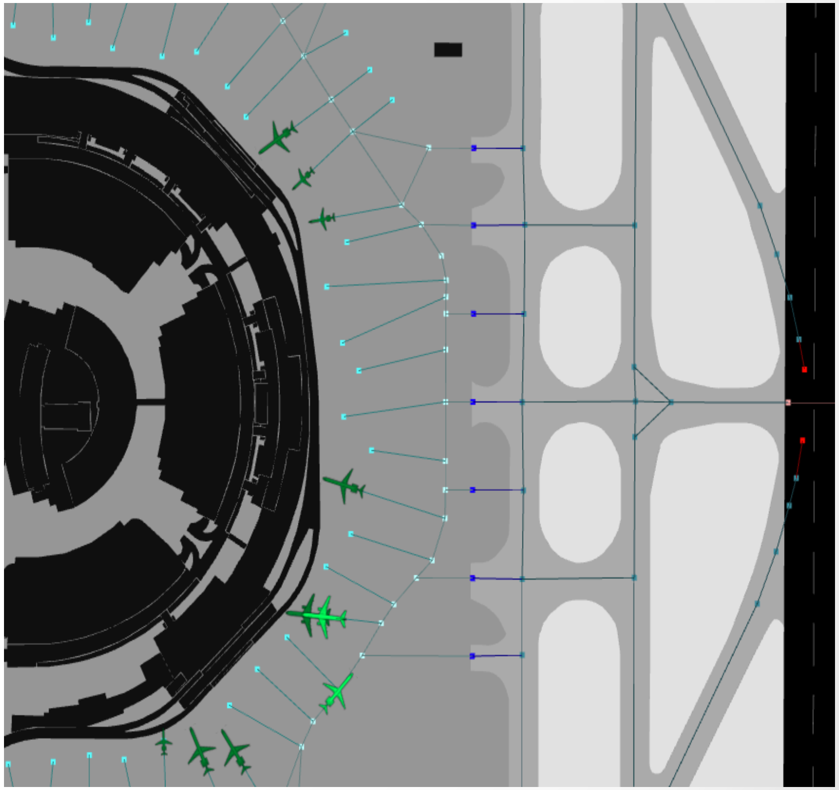


- Analyzes unmanned system mission plans to identify dependencies to monitor, assesses impact on plan of any detected contingencies
- Performs capability-based health assessment of vehicle state. Low-level sensor information is interpreted with respect to impact on operational capabilities such as system endurance, etc., mimicking human reasoning.



Airport Surface Simulation and Evaluation Tool (ASSET)

- A Simulator for modeling aircraft surface operations at airports.
  - Fast-time simulation environment.
  - Framework for rapid prototyping.
- An Evaluator for analysis of airport surface data.
  - Various metrics such as taxi-times, delays, number of stops, queue-lengths, throughput, fuels and emissions, and others.
- Inputs to Simulator
  - Graphical model of airport
  - Model of aircraft and separation constraints
- Scenario:
  - Aircraft, operation (departure arrival, runway)
- Simulator Outputs: route, times



ASSET Graphical Model of DFW

Fast Time Scenario Design

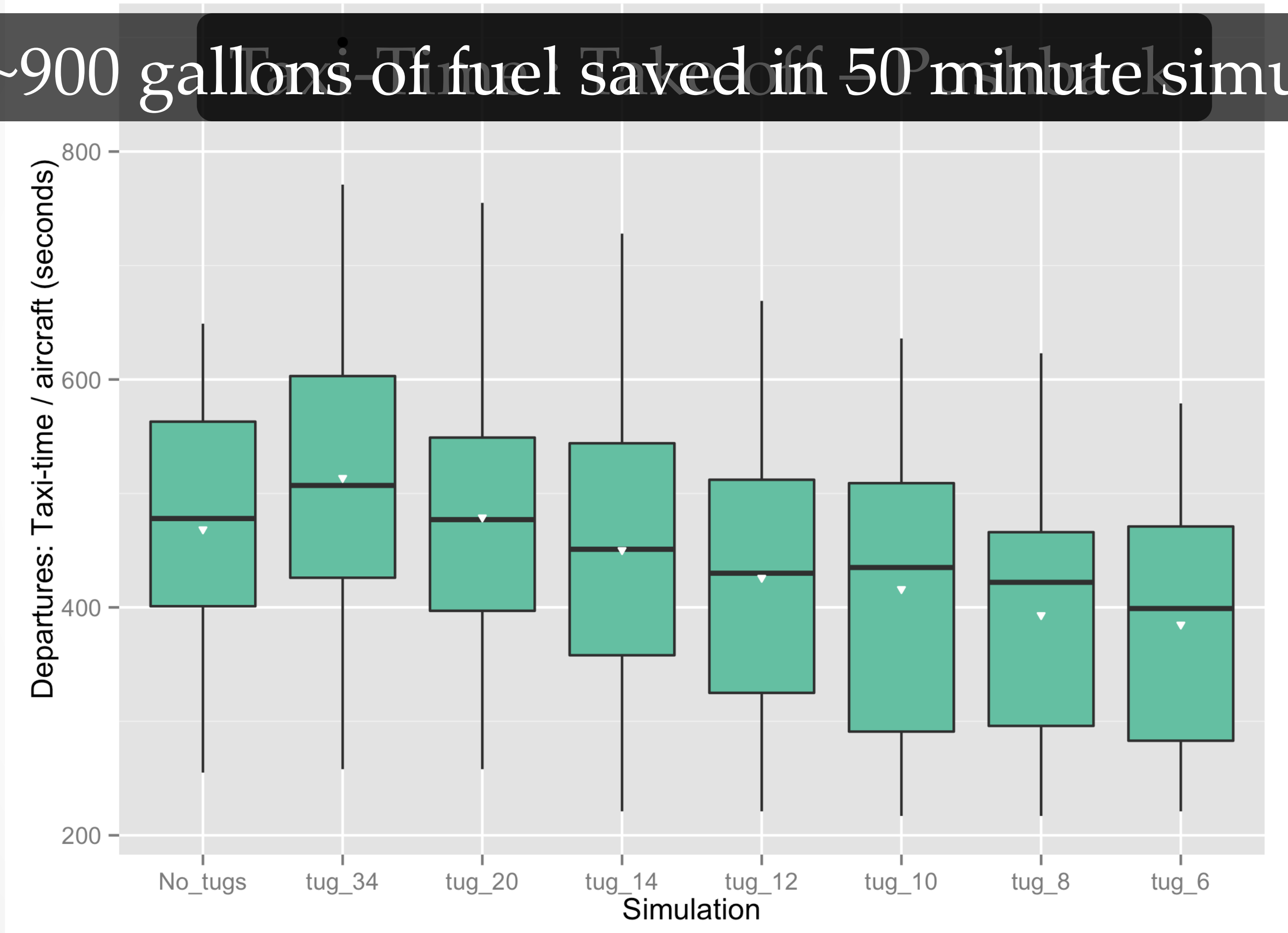
- Exploration Objective: *what if DFW has a tug-based taxi system?*
- Metrics to be evaluated in simulation: efficiency and environmental/economic impact of engines-off
- Characteristics: baseline (no tugs) compared with introduction of tugs on real data from DFW.
- Assumptions and limitations: nominal scenarios only, perfect communication, control and execution; departures only
- Level of maturity; used to form principles, eliminate poor design choices, define concept

Fast Time Scenario Design

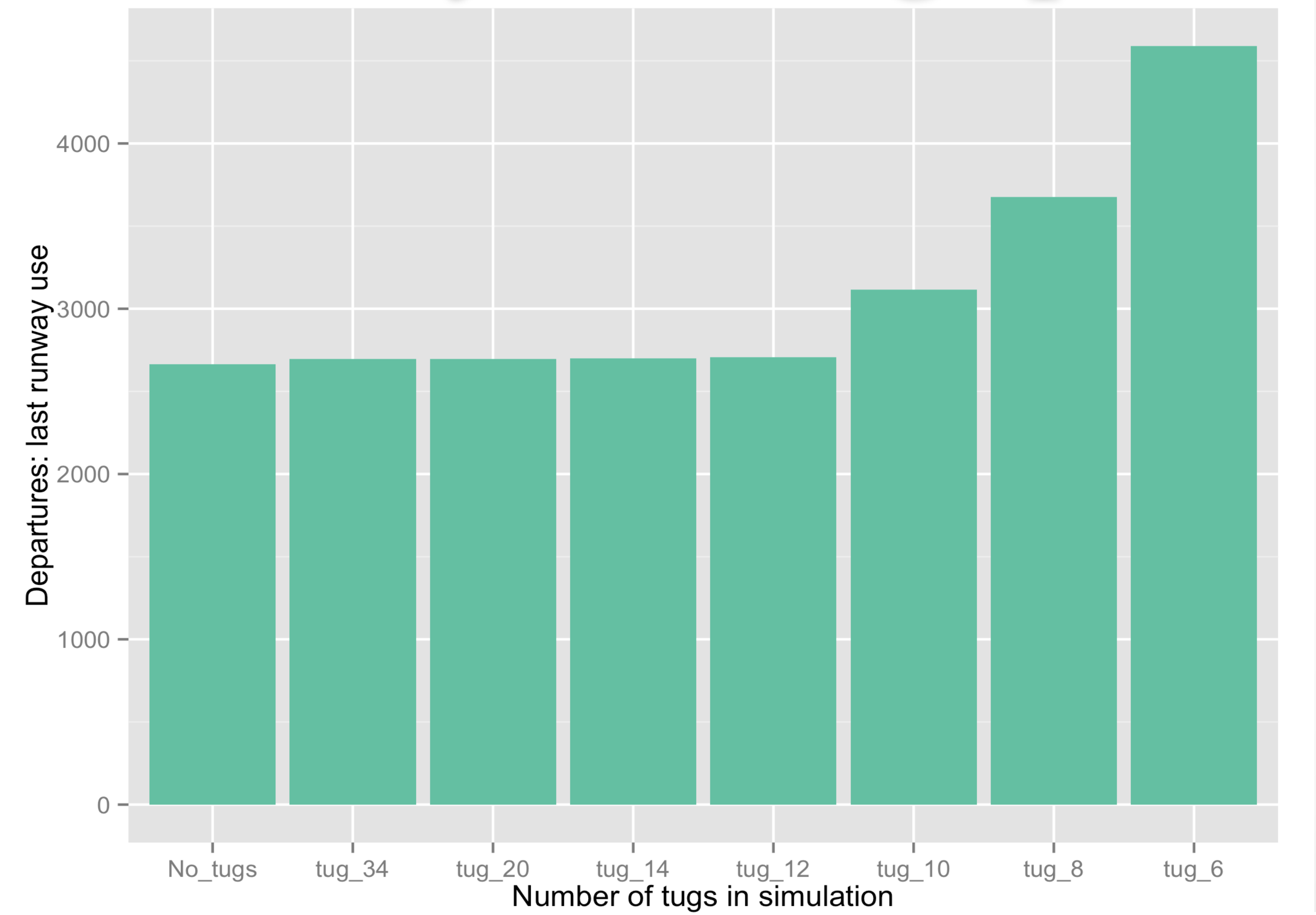
- Departures: 33, Arrivals: 15
- Two main tug depot with one depot for detached tugs.
- Number of tugs varied from 0 (Baseline) to 34 (at least one tug for each departure).
- Simulation assumes a time-duration for attachment and detachment of tugs.
- Tug dispatcher algorithm: Greedy heuristic that assigns tug to nearest and/or delayed aircraft.
- Homogeneous collection of tug (same performance).

Taxi-Times

~900 gallons of fuel saved in 50 minute simulation



Runway Throughput



Final Tug Autonomy Score Card

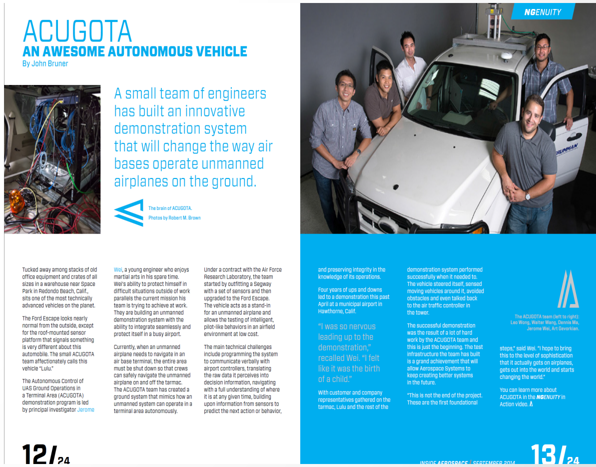
- Safety
  - ✓ High resolution sensing
  - ✓ Redundancy (pilot/crew can override tug if required)
  - X Predicting behavior in a mixed human/machine environment
- Effect on human workload and performance
  - ✓ Route planning and scheduling automated, not based on voice communication between pilot and controller
  - X Added complexity of mixed human/machine logistics
- Efficiency
  - ✓ Digital data link rather than voice communication allows more precision.
  - X Tugs require overhead of attaching/detaching and use of space
- Environmental/economic impact
  - ✓ Inherits all benefits of engines-off taxiing
  - X Requires infrastructure changes to airport surface

Airport Infrastructure Changes

- Fleet of size X to efficiently handle all arrivals/ departures
- Artificial Landmarks to aid tug navigation
- Wireless communication network (like a VPN)
- Tug depots/charging stations
- Tug supervisory system
  - Dedicated human team for monitoring tugs

Potential Future Work

- Controller automation
  - Heuristics and search for optimized route planning and scheduling using tugs
- HMI
- Autonomy
  - Field demo to test autonomy in real environment
- Simulation
  - Real time simulation for usability testing
- New tug applications
  - Surface management of UAVs



NGENUITY

ACUGOTA
AN AWESOME AUTONOMOUS VEHICLE
By John Bruner

A small team of engineers has built an innovative demonstration system that will change the way air bases operate unmanned airplanes on the ground.

The brain of ACUGOTA.
Photos by Robert M. Brown

Tucked away among stacks of old office equipment and crates of all sizes in a warehouse near Space Park in Redondo Beach, Calif., sits one of the most technically advanced vehicles on the planet.

The Ford Escape looks nearly normal from the outside, except for the roof-mounted sensor platform that signals something is very different about this automobile. The small ACUGOTA team affectionately calls this vehicle "Lulu."

The Autonomous Control of UAS Ground Operations in a Terminal Area (ACUGOTA) demonstration program is led by principal investigator Jerome Wei, a young engineer who enjoys martial arts in his spare time. Wei's ability to protect himself in difficult situations outside of work parallels the current mission his team is trying to achieve at work. They are building an unmanned demonstration system with the ability to integrate seamlessly and protect itself in a busy airport.

Currently, when an unmanned airplane needs to navigate in an air base terminal, the entire area must be shut down so that crews can safely navigate the unmanned airplane on and off the tarmac. The ACUGOTA team has created a ground system that mimics how an unmanned system can operate in a terminal area autonomously.

Under a contract with the Air Force Research Laboratory, the team started by outfitting a Segway with a set of sensors and then upgraded to the Ford Escape. The vehicle acts as a stand-in for an unmanned airplane and allows the testing of intelligent, pilot-like behaviors in an airfield environment at low cost.

The main technical challenges include programming the system to communicate verbally with airport controllers, translating the raw data it perceives into decision information, navigating with a full understanding of where it is at any given time, building upon information from sensors to predict the next action or behavior, and preserving integrity in the knowledge of its operations.

Four years of ups and downs led to a demonstration this past April at a municipal airport in Hawthorne, Calif.

"I was so nervous leading up to the demonstration," recalled Wei. "I felt like it was the birth of a child."

With customer and company representatives gathered on the tarmac, Lulu and the rest of the demonstration system performed successfully when it needed to. The vehicle steered itself, sensed moving vehicles around it, avoided obstacles and even talked back to the air traffic controller in the tower.

The successful demonstration was the result of a lot of hard work by the ACUGOTA team and this is just the beginning. The test infrastructure the team has built is a grand achievement that will allow Aerospace Systems to keep creating better systems in the future.

"This is not the end of the project. These are the first foundational steps," said Wei. "I hope to bring this to the level of sophistication that it actually gets on airplanes, gets out into the world and starts changing the world."

You can learn more about ACUGOTA in the NGENUITY in Action video.

The ACUGOTA team (left to right): Leo Wong, Walter Wang, Dennis Ma, Jerome Wei, Art Gevorkian.

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Questions?